ENGINE VALVEGEAR

The present invention relates to valvegear for engines of reciprocating piston type, in particular of spark-ignited type.

The inlet valves of reciprocating engines comprise a valve member cooperating with a valve seat and usually biased into the closed position by a return spring. The valve member includes a valve stem which is commonly acted on by one end of a pivotally mounted rocker arm, the other end of which is acted on by a cam carried on a rotary camshaft. The valve is opened periodically by a distance or lift which is determined by the geometry of the cam and air is drawn through the valve into the associated cylinder of the engine from the engine inlet duct.

The power produced by such engines is generally controlled by altering the position of a throttle valve situated in the engine inlet duct. At low engine load, the inlet duct is largely obstructed by the throttling valve and only relatively small volumes of air are introduced into the cylinders of the engine each time the associated inlet valves open. There is necessarily a pressure drop across the throttling valve, the magnitude of which increases as the throttling valve is progressively closed. This pressure drop is associated with pumping losses and at low engine loads these pumping losses can become very significant and constitute a significant inefficiency in the operation of the engine.

Many inlet valves are constructed and/or orientated to induce swirl or tumbling of the inlet air in the cylinder, that is to say rotation of the air about the cylinder

axis or about an axis perpendicular to the cylinder axis. This rotation is essential if efficient ignition and combustion of the fuel/air mixture is to occur. However, as the throttle valve is closed, the speed of the air through the inlet valve necessarily decreases and as it does so the vigour of the swirling or tumbling motion of the inlet air in the cylinder is reduced. This introduces further inefficiency into the operation of the engine at low engine loads.

It has long been known that it would be desirable to be able to dispense with the conventional throttling valve completely and to control the air flow into the cylinder merely by adjusting the lift of the valve, that is to say the extent to which the valve is opened. This would not only substantially reduce the pumping losses associated with the throttling valve at low engine loads but would also maintain the air speed through the valve at a high level at all engine loads, thereby eliminating the problem associated with inadequate swirl or tumble of the inlet air at low engine loads.

Many attempts have been made to devise valvegear which will permit the maximum valve lift to be varied in an inverse relationship to engine load. One example of such valvegear is that disclosed in EP-A-1039103. However, all such known valvegear is extremely complex and thus expensive.

It is therefore the object of the present invention to provide valvegear of the type referred to in which the maximum valve lift may be automatically reduced as the engine load is reduced but which is also simple and thus relatively cheap and reliable.

In accordance with one aspect of the present invention, valvegear for an internal

combustion engine of reciprocating piston type comprises a valve member which cooperates with a valve seat and is biased into the closed position by a spring, the valve member including a valve stem in contact with a pivotally mounted rocker arm, which carries a first roller in rolling contact with a first engagement surface on a rocking lever, which is mounted to pivot about a rocking shaft, the rocking lever having a second engagement surface in rolling contact with a second roller carried by an intermediate lever, the intermediate lever carrying a third roller in rolling engagement with a cam carried by a camshaft, the second engagement surface being of generally arcuate section, the distance between the second engagement surface and axis of the camshaft increasing in one direction of the arcuate length of the second engagement surface over at least part of its length, whereby a gap is defined between the second engagement surface and the cam lobe in which the third roller is received, the intermediate lever being connected to actuating means arranged to move it selectively in a direction transversely of the width of the gap.

Thus in the valvegear in accordance with this aspect of the present invention, the cam does not engage the pivotally mounted rocker arm directly but instead engages it indirectly via second and third rollers which are in engagement with an arcuate, e.g. circular, section engagement surface on a rocking lever which is pivotally mounted on a rocking shaft. The rocking lever also has a further engagement surface which is in rolling engagement with a roller carried by the rocker arm. The rocker arm may be of conventional type which is pivotally mounted and engages the valve stem at one end, frequently with the interposition of a tappet, or it may be of finger follower type, which is pivotally mounted at one end on a tappet and engages the valve stem at the other end. The intermediate lever is connected to actuating means which is arranged to

move it and thus the second and third rollers selectively transversely to the width of the gap, i.e. generally in the direction of the length of the gap defined between the cam and the second engagement surface. Thus as the point at which the second roller engages the second engagement surface moves along the second engagement surface, the angle through which the rocking lever will be displaced by the cam will alter and thus the distance through which the first roller will move over the first engagement surface will vary also. This will result in a variation in the maximum lift of the valve. The second engagement surface may be profiled to obtain the desired lift characteristics and variation in lift characteristics of the valve and its profile may be such that the lift of the valve always commences at the same point in the cycle, that is to say at the same time crank angle.

If the valvegear is intended for an engine with only a single inlet valve per cylinder or for an engine with two inlet valves per cylinder which are acted on by the same rocking lever, the second and third rollers may be one and the same, that is to say the intermediate lever carries only a single roller in engagement with both the cam and the second engagement surface. If, however, the valvegear is intended for an engine with two or even more inlet valves associated with respective rocking levers then the intermediate lever will carry a third roller in engagement with the cam and two or even more second rollers in engagement with the second engagement surface of respective rocking levers associated with respective valves.

The rocking lever may take various forms but in one embodiment it is elongate and affords the first engagement surface at one end and is mounted on the rocking shaft at a position adjacent the other end and the second engagement

surface constitutes part of one of its side surfaces. Thus in this embodiment, the second roller will engage the rocking lever at a point between the second engagement surface and the rocking shaft.

In an alternative embodiment, the rocking lever is elongate and affords the first engagement surface at one end and is mounted on the rocking lever at a point intermediate its two ends and the second engagement surface constitutes part of one of its side surfaces situated beyond the rocking shaft in the direction of its length away from the first engagement surface.

In accordance with a further aspect of the present invention, there is provided valvegear for an internal combustion engine of reciprocating piston type comprising a valve member which cooperates with a valve seat and is biased into the closed position by a spring, the valve member including a valve stem in contact with a pivotally mounted rocker arm, which carries a first roller in rolling contact with a first engagement surface on a rocking lever, which is mounted to pivot about a rocking shaft, the rocking lever carrying a second roller in rolling contact with a second engagement surface afforded by an intermediate lever, the intermediate lever carrying a third roller in rolling engagement with a cam carried by a camshaft, the second engagement surface being of arcuate section, the distance between the second engagement surface and the axis of the camshaft increasing in one direction of the arcuate length of the second engagement surface over at least part of its length, whereby a gap is defined between the second roller and the cam, in which the intermediate lever is received, the intermediate lever being connected to actuating means arranged to move it selectively in a direction transversely of the width of the gap. Valvegear in accordance with this aspect of the invention operates in a manner

which is substantially the same as valvegear in accordance with the first aspect of the invention but in this case the positions of the second roller and the second engagement surface are reversed. The gap is therefore defined between the second roller and the cam and it is the intermediate lever and the third roller which are accommodated in this gap.

The precise position of the intermediate lever and thus of the third roller may be varied in many different ways. In one embodiment, the intermediate lever is pivotally connected to one end of a control lever, the other end of which is connected to a control shaft which is connected to the actuating means which is arranged to move the control lever pivotally. This will result in the second and third rollers moving generally linearly, that is to say along the gap defined between the second engagement surface and the cam, though it will be appreciated that this gap is in fact of arcuate shape and that the second and third rollers are thus constrained to move in an arcuate path.

In an alternative embodiment, the intermediate lever is rotatably mounted on a control shaft which is connected to the actuating means to be rotated thereby about an axis which is eccentric with respect to the axis of the control shaft. Actuation of the actuation means will result in rotation of the eccentric shaft, which may be rotatably received in a hole in the intermediate lever, and this rotation will result in generally linear movement of the second and third rollers, though it will be appreciated that these are in fact again constrained to move along an arcuate path.

The precise shape of the second engagement surface will be selected to achieve the desired value of the maximum valve lift and the desired valve timing and

may be varied with wide limits. In one embodiment, the said distance increases progressively from one end of the arcuate length of the second engagement surface to the other end. Alternatively, the said distance decreases progressively from one end of the arcuate length of the second engagement surface and then increases progressively towards the other end.

Further features and details of the invention will be apparent from the following description of three specific embodiments which is given by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a scrap diagrammatic sectional view of a portion of the cylinder head of a multi-cylinder spark-ignited engine showing one inlet valve and one embodiment of the associated valvegear;

Figure 2 is a view similar to Figure 1 showing the valvegear in the reduced lift configuration;

Figure 3 is a view similar to Figure 2 of the second embodiment of the invention;

Figure 4 is a similar diagrammatic view showing the third embodiment of the invention; and

Figure 5 is a graph showing valve lift against crank angle at a variety of different settings of the valvegear illustrating the variation in the valve lift which may be achieved.

Referring firstly to Figures 1 and 2, the valvegear comprises a cylinder head 2, in which is formed an inlet port 4 communicating with one cylinder of the engine. Cooperating with each valve port is a valve member 6 shaped to form a seal with the valve port 2 and thus to close the valve. The valve member 6 is connected to a respective elongate stem 8 and is biased into the closed position by a spring 7. The end of the valve stem engages a so-called finger follower comprising a rocker arm constituted by a bar 10, one end of which engages the valve stem 8 and the other end of which is pivotably mounted on a hydraulic tappet 12. Rotatably mounted on the bar 10 is a rotatable roller 14.

Situated above the finger follower is a rocking lever 16, which is mounted for pivotal movement about a rocking shaft 18. The rocking lever 16 has two engagement surfaces 20 and 22. The engagement surface 20 is of complex shape, which will be described below, and is in rolling engagement with the first roller 14. The second engagement surface 22 is of part-circular section and is in rolling engagement with a second roller 24, which is rotatably carried by one end of an intermediate lever 26, the other end of which is pivotally connected to one end of a pivotal control lever 28. The other end of the control lever 28 is connected to a rotary shaft, which is not shown, whose axis is coincident with that of the shaft 18. The rotary shaft is connected to an actuator, which is shown only diagrammatically at 29 in Figure 1, arranged to rotate the shaft and thus to alter the angle of inclination of the control lever 28.

The second roller 24 is in rolling engagement not only with the engagement surface 22 but also with the surface of a cam 30, which is carried by a camshaft 32. The engagement surface 22 and the cam 30 thus define a gap in which the second roller 24 is accommodated. The engagement surface 22 is of arcuate, in

this case part-circular, section and the centre of the circle is offset from the axis of the camshaft, whereby the distance between the engagement surface 22 and the axis of the camshaft increases progressively from one end of the surface 22 to the other end. This means that the width of the gap progressively increases also, specifically in the direction towards the valve member and first roller, when the lobe of the cam is directed away from the rocking lever 16, as shown in Figure 1.

As the camshaft rotates, the roller 24, which is in rolling contact with the cam 30, will be periodically displaced to the left, as seen in Figure 1, thereby resulting in the rocking lever 16 being moved in rotation in the clockwise direction. The inclined shape of the engagement surface 20 will mean that as the surface 20 rolls to the left in Figure 1 across the roller 14, the finger follower will be depressed downwardly and the valve will be opened. If the actuator connected to the rotary shaft is actuated, the control lever 28 will be caused to move in rotation, thereby moving the roller 24 along the length of the gap between the engagement surface 22 and the cam 30. The roller 24 may therefore move between e.g. the position shown in Figure 1 and that shown in Figure 2. It will be appreciated that the closer the roller 24 is to the pivotal axis of the rocking shaft 28, the greater will be the lateral movement of the engagement surface 20 to the left, when the cam is at full lift, and thus the greater will be the distance moved by the valve 6, that is to say the greater will be the lift of the valve 6. Accordingly, the maximum lift of the valve may be varied, as desired, by appropriately moving the control lever 28 by means of the actuator. In practice, this will be effected automatically by the engine management system, with which modern engines are now equipped, in response to one or more sensors which detect e.g. the position of the accelerator pedal,

the speed of the engine and/or the load to which it is subjected. Thus at low engine load, a relatively small amount of lift of the inlet valve 6 is desired and the roller 24 is therefore moved to a position similar to that shown in Figure 2 in which it is a relatively large distance away from the rocking shaft 18 whilst under high load conditions, when a greater valve lift is desired, the roller 24 is moved into a position similar to that shown in Figure 1.

Figure 5 shows the variation of the valve lift in mm against the angle of the crankshaft in degrees at various different positions of the roller 24. As may be seen, the further away from the shaft 18 the roller 24 is moved, the smaller is the maximum lift of the valve. Furthermore, as the maximum lift of the valve is reduced, the time at which the maximum lift occurs becomes progressively earlier in the cycle. It will, however, be appreciated that the detailed shape of the engagement surface 20 may be varied at will to provide a wide variation in the detailed time/lift characteristics of the valve.

The modified embodiment shown in Figure 3 differs from that shown in Figures 1 and 2 in a number of respects. Thus firstly, the rocking shaft 18 is not provided at the end of the rocking lever 16 opposite to the engagement surface 20 but is provided approximately half way along the length of the rocking lever 16. Secondly, whilst the embodiment illustrated in Figures 1 and 2 is intended primarily for an engine with a single inlet valve per cylinder, that shown in Figure 3 is intended for an engine with two inlet valves per cylinder. There are therefore two rocking levers 16 associated with each cylinder, each of which cooperates with a respective inlet valve 6. The two rocking levers 16 are however operated by a single cam 30, which is positioned midway between the two rocking levers 16 in the direction of the length of the camshaft 32. This

does of course mean that the second roller 24 in rolling engagement with the cam is not aligned with the engagement surfaces 22 on the two rocking levers 16. The intermediate lever 26 therefore carries two second rollers 34 in rolling engagement with the engagement surfaces 22 of respective rocking levers 16. The three rollers 24, 34 may be mounted to rotate about a common axis or about different axes. It will be seen that the rollers 34 engage the rocking levers 16 at positions which are further from the engagement surface 20 than from the rocking shaft 18. This means that when the cam lobe 30 engages the third roller 24 and thus displaces the upper end of the rocking lever 16 to the left as seen in Figure 3, the engagement surface 20 moves to the right rather than to the left, as in the embodiment of Figures 1 and 2.

The adjusting mechanism in the embodiment of Figure 3 also differs from that in Figures 1 and 2. Thus the intermediate lever 26 is mounted to rotate with respect to a control shaft 36, which is itself mounted to rotate about an eccentric axis 38. Accordingly, rotation of the control shaft 36 by the actuator about its eccentric axis 38 will result in the rollers 24, 34 being moved in the direction transverse to the width of the gap between the cam 30 and the rocking lever 16 and thus in the maximum lift of the valves being altered.

It will be seen also that the engagement surface 20 in rolling engagement with the first roller 14 is divided into two sections of very different shape. The first section 20', with which the roller 14 is in contact when the third roller 34 is in contact with the base circle of the cam 30, is of part-circular section, the centre of the circle being coincident with the axis of the rocking shaft 18. This is, however, not essential and the section 20' may be merely of arcuate but non-circular shape. The second portion 20" of the surface 20, with which the roller

14 comes into rolling contact after some initial lateral movement of the engagement surface 20 has occurred, is also arcuate, but in the opposite sense to the section 20'. Accordingly, as the rocking lever starts to move in the anticlockwise direction as the lobe of the cam 30 begins to displace it, the finger follower is initially not displaced at all. However, when the roller 14 comes into rolling contact with the second portion 20" of the engagement surface 20, the finger follower starts to be displaced downwardly and the valve 6 starts to open.

Figure 4 shows yet a further embodiment which is similar to Figures 1 and 2 in that the rocking shaft 18 is provided at the end of the rocking lever 16 opposite to the engagement surface 22. However, the positions of the second roller 24 and the engagement surface 22 have been reversed and the roller 24 is now rotatably carried by the rocking lever 16 whilst the engagement surface 22 is carried by the intermediate lever 26. The adjusting mechanism is similar to that shown in Figure 3 and the intermediate lever 16 is mounted to pivot about a control shaft 36 which is eccentrically connected to the rocking shaft 18. The actuator is connected to rotate the shaft 18 and when it does so the intermediate lever 26 is caused to move transversely to the width of the gap defined between the roller 24 and the cam 30, thereby altering the maximum lift of the valve 6. The distance between the engagement surface 22 and the cam 30, or more specifically its axis, does not increase progressively along its entire length but instead decreases progressively from one end to approximately the middle of the surface 22 and then increases progressively towards the other end. Although the surface 22 is generally arcuate, it will be appreciated that its detailed shape may be adjusted as required in order to be able to obtain the variation in the maximum lift/timing of the valve 6 that is desired.

It will be appreciated that numerous modifications may be effected to the embodiments described above. The precise profile of the valve lift including the times at which the valve opens and closes, the maximum lift obtained at any particular setting of the valvegear and the profile of the movement of the valve between its closed and fully open positions may be varied by varying the positions and/or sizes of the various rollers and by varying the profile of the engagement surfaces. The camshaft may also be provided with a phase shifter of conventional type which may be operated selectively to change the phase of the camshaft with respect to that of the engine crankshaft by up to 30° or even more so as to selectively vary the phasing of the open period of the valve. Whilst it is anticipated that the valvegear in accordance with the invention will be used predominantly in connection with the inlet valves of an engine, it is also desirable alternatively or additionally to use the valvegear in connection with the exhaust valve of an engine.